

## ABSTRACT

Motivated by the perceptual characteristics of the Human Visual System (HVS), the thesis is concerned with the creation of a general framework for image compression, invoking the HVS

It is found that an image can be compressed without any *significant* loss of "information" if it can be appropriately coded. Conversely, information can be extracted from the compressed image by a corresponding decoding process

If we examine the natural and synthetic images, we notice that the gray/color values of the pixels in a neighborhood are very close. In other words, the intensity values of adjacent pixels do not differ widely or there exists some correlation or redundancy among the pixels in a neighborhood. Methods employed in the literature to minimize the redundancy and reduce the correlation among the pixels are known as **image coding schemes**. Such schemes yield a compact representation of the original image without losing its details, thereby leading to image compression. In this context, the literature also employs many terms, like *source coding*, *digital coding*, *data compression*, *bandwidth reduction* or *signal compression*, in order to connote techniques used for achieving a compact digital representation of a signal or image.

The motivation for the contents of the thesis arose from the primal role played by human visual characteristics in perception. It is a fact that most of the applications, involving images or video sequences (as generated, for instance, in television or video conferencing), are primarily meant for humans. Therefore, it is imperative that the special (neuron-based) characteristics of human perception be incorporated into any image coding scheme for better performance. Perceptually, if a reconstruction of an image from the compressed data *cannot be visually* distinguished from its original, then the compression scheme is considered to be efficient in terms of both the *quality of reproduction* of the images and their *compact representation*. In short, the characteristics of the eye and of the HVS should form an integral part of any image coding scheme. HVS properties that are relevant to compression of images are (i) nonlinear behavior of the visual response, (ii) contrast sensitivity behavior to visual stimuli, (iii) maximum sensitivity along the vertical and horizontal

directions of the patterns, (iv) bandpass characteristics of the channels having a bandwidth of one octave, (v) high sensitivity to low frequencies, (vi) high correlation among the three components (red, green and blue) of color signals, and (vii) better sensitivity to intensity than to chrominance of a color stimulus

This thesis is organized as follows

We survey, in Chapter 2, some of the existing and innovative methods (like transform coding, Vector Quantization(VQ), Block Truncation Coding(BTC), subband Coding, fractal coding etc ) and algorithms that have been proposed in the literature to code images and video signals. We also present, in a concise form, some of the well known standards suggested for image coding

In Chapter 3, we describe some of the salient characteristics of the HVS, and critically examine the existing models. Our main contributions relate to *(i) the spatial frequency model based on the HVS, and (ii) the development of algorithms for adaptive perception-based image coding schemes in the spatial and frequency domains, in order to achieve better compression.* As applied to some of the standard images ('Baboon', 'Airplane', and the like — see Table 1 below), the results obtained from our methods show significant improvements over those of the recent literature. More specifically, among the existing coding methods, the standard BTC Coding or Absolute Moment BTC (AMBTC) methods yield a compression rate of 2 bpp (*bits per pixel*) [27-28]. On combining with VQ, these methods achieve a rate of 1.675 bpp [29]. In contrast, the results of [85], using a hybrid VQ, (which is a combination of BTC, DCT and VQ), indicate an improved compression rate and Peak Signal to Noise Ratio (PSNR) which are reproduced in Table 1

Table 1

Image	Rate (bpp)	PSNR
Pepper	0.406	28.96
Baboon	0.452	21.74
Airplane	0.409	29.06

The methods proposed in this chapter, which exploit the characteristics of the HVS in coding the images, achieve better compression rate and PSNR values. Also, the subjective tests confirm that the performance of the coding algorithms is good in terms of the '*perceptually good*' reproduction of the images. Corresponding results of the thesis are presented below in Table 2 for the perception-based adaptive coding method.

Table 2

Image	bpp	PSNR
Pepper	0.394	32.99
Baboon	1.136	29.38
Airplane	0.442	34.05
Announcer	0.352	31.62
Flower	0.319	34.18
Model	0.248	35.49
Sailboat	0.762	32.39

Another aspect of the thesis is the coding of color images. It has been found that color perception in humans cannot be obtained directly from the responses to intensity information alone. We need to consider chrominance also, while trying to exploit color vision models for compression. In an attempt to generalize the model proposed for image compression, we invoke, in Chapter 4, the characteristics of the HVS with respect to color signals as inputs, and analyze a few of the possible color models. In this context, correlation among the three components of color is exploited to compress color images to an extent greater than what is possible by compressing, *separately*, its principal color components. It turns out that algorithms developed to compress color images are not merely application of algorithms employed to code the monochrome images. Our unified approach exploits the correlation among the three components, as also similarity of various features of the image in the three components.

The proposed methods to code the color images achieve, on the average, a bit-rate of about 3 bpp, in contrast to the standard BTC methods which

yield a *constant* bit-rate of 4. Results presented in [82] in which color images are coded with BTC, followed by the adaptive DCT techniques, indicate that an average bit-rate of about 2 bpp is achieved using  $R$ ,  $G$  and  $B$  components, whereas an average rate of 1.675 bpp is achieved for  $Y$ ,  $I$  and  $Q$  components. As against this, our methods, in which we exploit not only the HVS response to color, but also the correlation that exists among the three color components, result in a compression of color images with average bit-rates 3.2 and 2.7, using  $R$ ,  $G$  and  $B$  components, and  $Y$ ,  $I$  and  $Q$  components, respectively. It is to be emphasized here that these results have been achieved only by exploiting the HVS characteristics and the correlation among the bands, *without* employing any adaptive DCT methods, unlike the results of [5]. It should be possible to achieve a superior compression rate by combining these methods with our coding scheme.

To demonstrate the applicability of the proposed methods using the HVS models to a topical problem, we deal, in Chapter 5, with the problem of coding and recognition of monochrome facial images. Our main objective here is to combine the properties of HVS, DCT and the Principal Component Analysis (PCA) method to achieve an efficient representation scheme to encode the face images for subsequent recognition. It is not appropriate to consider a set of face images merely as a group of ensembles and to subject them to statistical analysis without considering the nature of the ensembles, as had been considered in the earlier works (see, for instance, [111-113]).

We propose a new method for encoding and recognizing human faces in gray level images, based on *the DCT coefficients, Principal Component Analysis, and the characteristics of the HVS*. In this approach, we incorporate the characteristics of the HVS to represent the face images containing various features in a specific form which is also compact. We demonstrate the superiority and advantages of the proposed method with some illustrations.

We conclude the thesis in Chapter 6 with an indication of a possible extension of the proposed methods to code image sequences.